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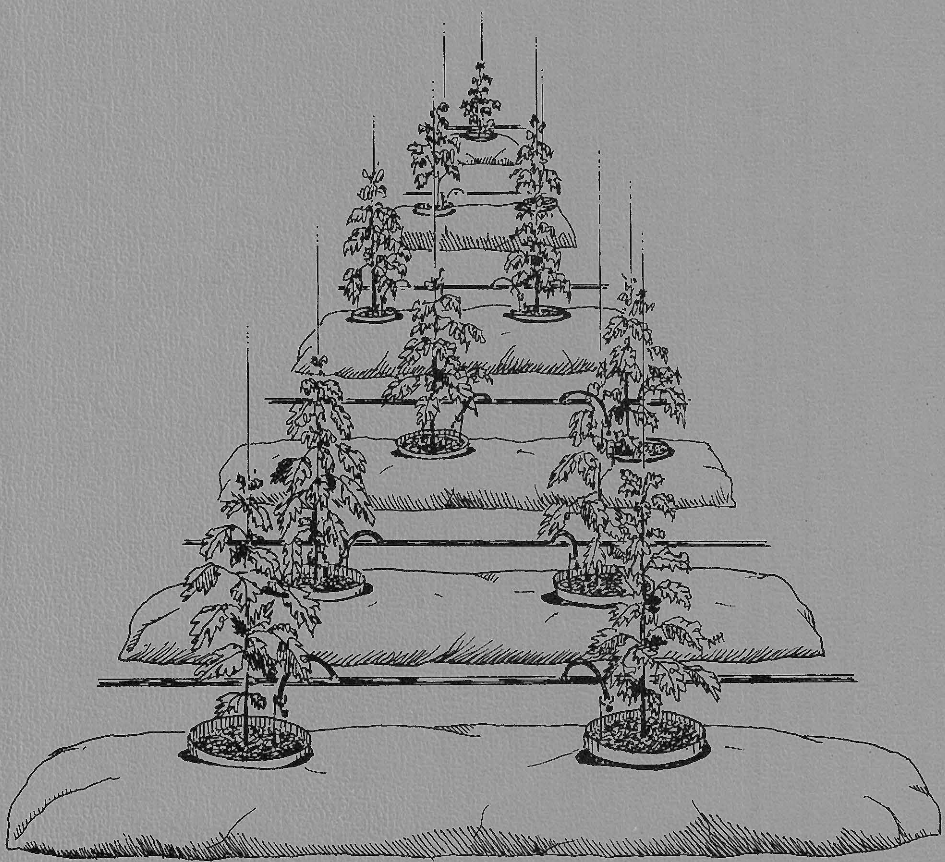
Bag Culture Production of Greenhouse Tomatoes



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INTRODUCTION

With increasing costs of energy, growers have been seeking energy-efficient alternatives for growing greenhouse tomatoes, especially those alternatives which would eliminate the need for steam sterilization of soil. Several systems have been explored, including hydroponic (NFT), gravel culture, sand culture, and others.

For the immediate future there is a new system which shows considerable merit—growing crops in a peat-vermiculite mix placed in plastic bags, which are then oriented into rows in the greenhouse (Fig. 1). Research has been done on other types of soilless culture in other areas where greenhouse tomatoes are being grown (2, 3, 4, 5, 7). This particular bag culture system has been investigated and tested over four growing seasons in greenhouses at the Ohio Agricultural Research and Development Center (OARDC). The experiments have defined cultural practices which should be used in commercial bag culture tomato crop production in greenhouses.

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MAIN REASONS FOR INTEREST IN BAG CULTURE CROPPING

The bag culture system of greenhouse vegetable production has proven highly successful and offers a number of advantages over conventional planting in soil ground beds. These include:

- Soil steaming is not required.
- Peat-vermiculite is a more uniform medium than soil.

FIG. 1.—Rows of tomato plants growing in bag culture which are automatically watered and fertilized by drip irrigation system.

- Control of plant growth is more precise.
- Faster crop turnaround is possible.
- It is easier to control fusarium crown rot (at least within the first cropping period), and control of soil diseases and insect pests is more effective.
- It promotes a favorable early yield.
- Uniform and controlled watering is possible with newly developed "Agrifim" irrigation systems.
- Labor costs are lower than with a soil-grown crop, particularly those costs related to soil steaming and preparation and the ability to work in a crop without delays due to overhead watering.
- Crop mulching techniques can be changed to provide higher light intensities in the crop, potentially increasing yields.
- There is better utilization of energy where bag culture is used. The system permits irrigation and controlled optimum use of water, no demand periods of water usage, and reduction in energy required to dry the crop (currently required by conventional systems).
- The system offers optimum use of fertilizers and reduction in fertilizer usage.
- There is a cation exchange buffering action with peat and vermiculite which is higher than in many soils, and hydroponic systems have little or no CEC at all.
- Unlike hydroponic systems, there is no recirculation of spent nutrient water in the bag culture system. Thus disease introduction by water is virtually eliminated.

MATERIALS AND METHODS

Media Volume and Formulas

Plants are grown in commercially prepared or grower-filled bags which contain between 0.50 and 0.75 ft^3 of medium per plant.

Many different types of peatlite formulas can be used successfully. At the OARDC, the following formula has been used with excellent repeatable success.

per Cubic Yard of Material

11 bu peat
11 bu vermiculite (either No. 2 or No. 3)
1.5 lb potassium nitrate*
2.0 lb superphosphate (0-20-0)
10 lb dolomitic limestone
(80% passing through 100-mesh screen)
1 oz iron chelate 330 (10% Fe)
0.8 oz boric acid (17.48% B)

* The potassium nitrate, iron, and boric acid can be dissolved together in warm water and incorporated to the mix as a solution.

Bag Types and Sizes

The plastic bags (tubes) used for the peatlite medium should be white, of at least 4-mil thickness, and made of UV-resistant polyethylene material for longer life.

Barring bag contamination by pathogenic fungi, research has shown that the medium life is at least 3 years. Common bag size is 15 by 48 inches, although other sizes of horizontal, lay-flat bags have worked well.

Research has been conducted at the OARDC to define the volume of medium necessary to produce maximum yields of high quality tomatoes. Medium volumes between 0.25 ft^3 and 1.25 ft^3 were tested. Results from these replicated experiments show that medium volumes of 0.50 ft^3 per plant were sufficient to produce a maximum yield of high quality tomatoes (10).

Time and Temperature for Seeding

Time from seeding to pricking out into 4-inch pots should be approximately 10 days.

Temperature of the seeded flat should be maintained at 75° F until seedling emergence. During this time the germination medium should be kept moist. Germination is a critical time and variation in moisture levels can result in death of young, developing seedlings. After emergence, the young seedlings can be grown at temperatures of 62° F night and 75° F day.

Pricking Out and Transplanting

Prior to pricking out, peatlite medium should be placed in 4-inch bottomless pots (Fig. 2). Pricking out the young seedlings can be accomplished by placing the seedling root in the middle of the pot and gently pushing down on this root with the index finger until the seedling is below the surface of the medium to approximately one-half its length. Firming the mix around the planted seedling is important, as is a thorough watering immediately following pricking out.

It is important to grow a stocky transplant. Transplants should be kept moist after pricking out and as they start to root and grow. Watering at this point must be based on environmental conditions—sunlight and humidity. Ambient temperatures for transplants should

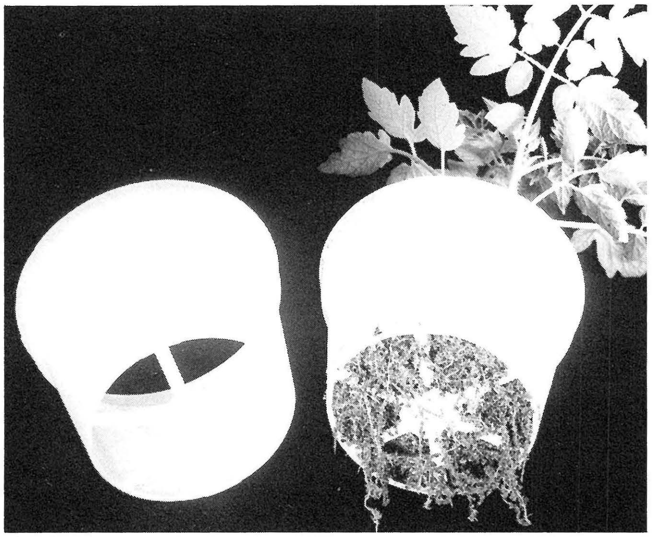

FIG. 2.—Four-inch plastic, bottomless pots for starting young transplants.

be 62°-65° F night/day for low light days, and 62°-78° F night/day for high light days.

Transplants can be held for a few days by lowering the night temperature to 55°-58° F and day temperature to 62° F. Average transplant growth time is as short as 4 weeks during the summer and as long as 8 weeks during the winter.

Transplants should be fertilized at the low nitrogen range indicated in the liquid feeding schedule (Table 1) until they are placed in the bags.

Preparation of the Greenhouse and Planting

The greenhouse should be thoroughly cleaned and all extraneous material removed. With a soil floor, furrows approximately 3 inches deep and 28 inches wide should be made to facilitate removal of any excess water from the double rows of bags and to keep the worker walk rows dry (Fig. 3). Four-mil white plastic should be used to cover the floor to reflect and increase light, reduce humidity and disease, and facilitate cleanliness.

Next, the bags containing the medium should be placed in double rows at the proper spacing, with the irrigation system placed next to the bags between the double rows. Holes approximately 5 inches in diameter should be cut in the bags at the proper spacing desired for the crop (see section on Spacing of Plants in Bags). The potted transplants are then placed in the holes and set at one-quarter depth of the pot.

The irrigation emitter is placed in the pot so that the water drips onto the top of the pot (Fig. 4). The irrigation system should be turned on immediately after transplanting and run at intervals until a gallon of fertilizer-enriched water has been applied to each plant. This also provides wetting of the dry medium in the bag. After the medium in the bag has been allowed to settle and become uniformly wet, side slits should be made in the bags. Two side slits, 2½ to 3 inches long, should be made in the bags horizontal to the floor and one-third from the bottom of the bag.

Spacing of Plants in Bags

Different spacing arrangements have been used successfully for tomatoes. A common spacing of tomatoes to achieve approximately 10,000 plants per acre is 17 inches between plants within the row, 23 inches between double rows, and 42 inches in the walk rows.

TABLE 1.—Liquid Fertilizer Feeding for Bag Culture.

	Dilute Irrigation Feeding* mg/liter (ppm)†								
Type of Feed	N	P	K	Ca	Mg	Fe	B	Type of Fertilizer	State of Plant Development and/or Remarks
Complete Low Nitrogen	150 to 200	50	225 to 300	80	30	3	0.5	Potassium Nitrate, Calcium Nitrate, Phosphorus, Magnesium, minors	From plant bags until first cluster is set
Medium Nitrogen	200 to 225	50	300 to 340	80	30	3	0.5	Potassium Nitrate, Calcium Nitrate, Ammonium Nitrate, Phosphorus, Magnesium, minors	From first until fourth cluster is set
High Nitrogen	225 to 300	50	340 to 500	80	30	3	0.5	Potassium Nitrate, Calcium Nitrate, Ammonium Nitrate, Phosphorus, Magnesium, minors	Fourth cluster until before crop termination
Phosphorus		50						Phosphoric Acid	Also used to maintain pH of irrigation water to prevent scale in irrigation lines
Calcium				80				Calcium Nitrate	Should not be mixed with magnesium sulfate in fertilizer stock
Magnesium					30			Epsom Salts	Should be kept separate from monoammonium phosphate as a mixture can cause blocking of irrigation lines
Iron						3 to 10		Iron Sequestrene	Approximately 100 ppm iron should be maintained on foliar analysis reports
Boron							0.5	Boric Acid	Maintain 50 ppm boron on foliar analysis
				150				Calcium Nitrate	To control blossom end rot.

*Conductivity of nutrient-enriched irrigation should range between 1800 and 2900 μ-mhos or 1.8 to 2.9 milli-mhos.

†Example: To obtain 440 ppm K_2O from potassium nitrate, which is 44% K_2O, and the proportioner gives a 1:100 dilution, the stock tank mix must be 44,000 ppm in 4.4% K_2O. A 1:10 dilution of potassium nitrate would provide this mix. The proper ratio is 1 lb of potassium nitrate dissolved in 10 lb of water (1.16 gal) or 0.86 lb of potassium nitrate dissolved in 1 gal of water.

FIG. 3.—Preparation of the greenhouse floor before planting. The planting consists of furrows and ridges covered with white polyethylene.

Research has shown repeatedly that the optimum spacing for a greenhouse tomato crop in the northeastern United States is approximately 3½ to 4 ft^2 per plant.

Watering Plants

A clean water supply is important to insure minimum operational problems, and all necessary measures must to be taken to insure a clean, high quality supply.

Although some work has been accomplished on one-time incorporation of slow-release fertilizer into the medium (6), constant feeding with fertilizer permits better plant nutrient control. Therefore, fertilizer should be included in each irrigation (Table 1).

Watering may be on a once-a-day schedule when the plants are young, as long as wilting does not occur. As the plants begin to grow, additional water should be supplied by increasing the frequency of irrigation. The greatest need for additional watering will be on bright, sunny days. A rule of thumb is to water until some water is observed coming out of the slits in the bags.

A fully grown tomato plant may use as much as 3,000 ml or 107 oz of fertilizer-enriched water per day during late spring and summer growth.

Heated Water

Research has confirmed that warm water at root temperatures of 60°-86° F has given plant growth advantages (1, 6). Warm water stimulates the roots to continue to grow at a normal rate. Use of cold water that lowers the medium temperature to 58° F or lower reduces root growth and may even cause wilting of the foliage on a bright sunny day.

Fertilization

Different types of fertilizer may be used. The following lists types of fertilizer containing the necessary elements:

Nitrogen (N)
potassium nitrate
ammonium nitrate
calcium nitrate
diammonium phosphate
nitric acid

Phosphorus(P)
phosphoric acid
ammonium phosphate
super phosphate
(not soluble form)

Potassium (K)
potassium nitrate
potassium sulfate
muriate of potash

Calcium (Ca)
calcium nitrate
dolomitic limestone

Magnesium (Mg)
magnesium nitrate
magnesium sulfate

Iron (Fe)
iron chelate 330
liquid chelate iron

Boron (B)
boric acid

Other Minerals
Peters Soluble Trace Element Mix (Compound 111)†

†Used as an ingredient in preparation of the peatlite mix.

pH Maintenance of Irrigation Water

Maintenance of the pH of water at the fertilizer injection point, as well as throughout the irrigation system, is extremely important to prevent chemical reaction of the fertilizers in the irrigation lines. Therefore, a continuous pH monitoring system is recommended (Fig. 4). To maintain an in-line pH of 5.5 to 6.0, an operating pH of 5.8 is recommended.

High solution pH (6.4 and higher) can cause precipitation by chemically forming calcium hydrogen phosphate in the irrigation lines. Formation of bicarbonates also occurs at pH 6.4 or higher. In a low pH solution (3.0), iron phosphates begin to form and other elements precipitate, all of which can clog the irrigation lines and result in uneven watering or no water flowing from the emitters to the plants. Again, solution pH maintenance is very critical to assure proper operation of the irrigation and plant growth systems.

Caution: A pH below 4.0 can cause injury to plant roots.

Acids

Several acids can be used to maintain the irrigation water pH and feed the plant: phosphoric acid (H_2PO_4), nitric acid (HNO_3), sulphuric acid (H_2SO_4).

The amount of acid to add to the water to maintain pH of 5.8 varies due to initial hardness of the water and the amount and type of fertilizer in the water. If the

FIG. 5.—Mohr control in-line pH and conductivity meter.

FIG. 4. Holes in bags for placement of plants in bottomless pots and placement of irrigation water.

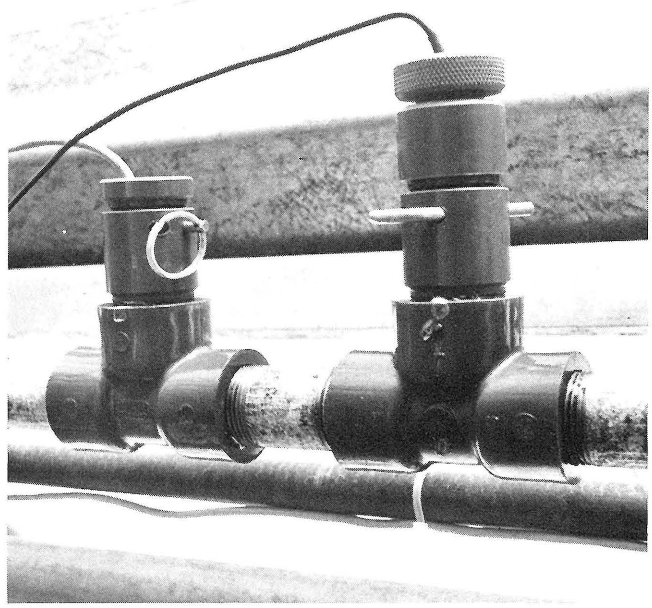

FIG. 6.—The in-line probe for measuring ph and conductivity of fertilizer-enriched irrigation water.

enriched water has a pH of more than 6.8 after mixing the various concentrations of fertilizers, a good rule of thumb is to add 2 oz of acid per 100 gallons of the final dilution water going on the plants. The importance of proper maintenance of the pH of the fertilizer water cannot be over-emphasized.

Measuring Water Conductivity

An in-line conductivity meter which measures nutrient solution concentration is important. This meter should be equipped with an alarm system for high and low concentrations of salts (Figs. 5, 6).

Concentration of Nutrient Irrigation Solution

Total concentration of nutrients in solution varies with the time of year and stage of development. The range of nutrient solution concentration should be from 500 to 3,000 Mmhos. The following is a recommended average total electrical conductivity (EC) for the growth of a tomato crop.

Stage of Crop	Total EC Concentration
Transplanting-3rd cluster development	1800 to 3000
4th cluster-7th cluster development	1800 to 2400
7th cluster-12th cluster development	1500 to 2300
12th cluster development-termination	800 to 1800

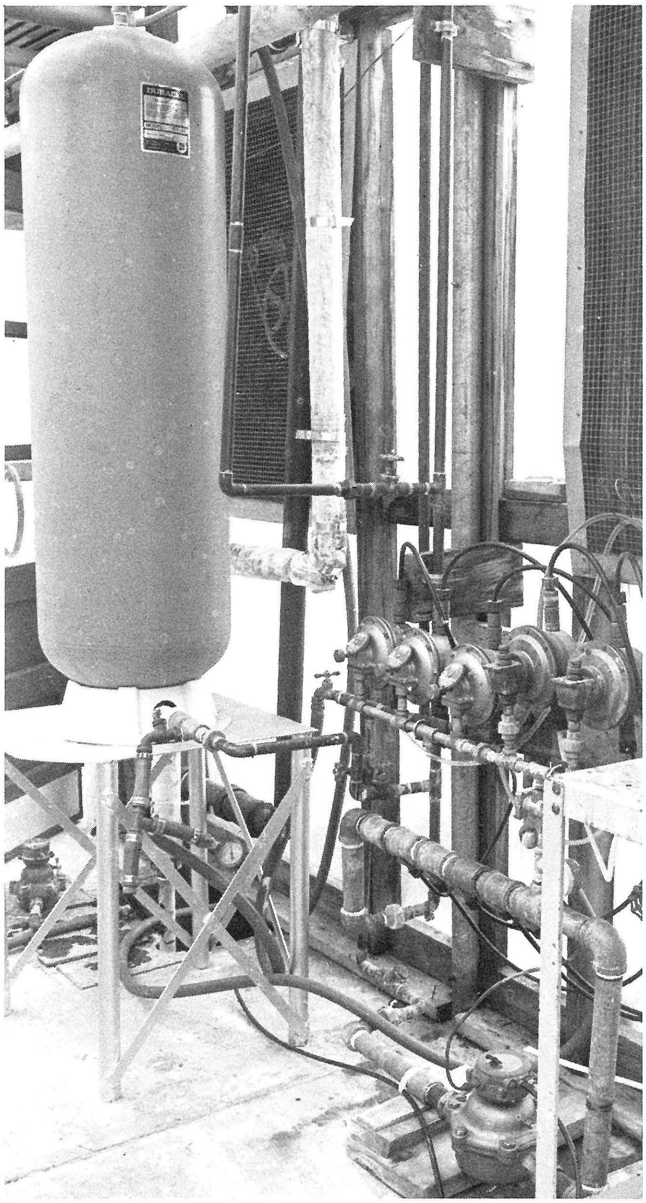

FIG. 7.—A typical "Anderson" fertilizer injection unit with multi-heads and mixing tanks.

Testing for and Maintaining Proper Bag Conductivity

Injection of fertilizers in the irrigation water can result in a build-up of fertilizer conductivity in the medium. This build-up of fertilizer conductivity is caused by the plant taking up water at a faster rate than it takes up fertilizer. A build-up of fertilizer conductivity to critical root osmotic stress levels can cause a reduction in plant foliage and root growth, with higher levels resulting in root death. On an average, fertilizer conductivity levels of the medium should be 200-500 Mmhos above the conductivity of the fertilizer-enriched irrigation water. The critical level of medium conductivity is different for different crops. For example, in tomatoes it is about 3,000 Mmhos. To be sure the level falls in a range below 3,000 Mmhos, medium conductivity tests should be taken weekly or at least bi-weekly.

Leaching of the medium with clear water will result in flushing out excess nutrients in the medium. This process should be followed with a light feeding of fertilizer solution to replace the nutrients in the root area of the medium. The medium may then be retested for conductivity by obtaining a sample in one of the following ways:

- If the medium is saturated with water, a sample for conductivity testing may be obtained by taking a medium sample from the midsection of the bag and squeezing enough fertilizer water out to obtain a reading. A better procedure is to obtain a sample of water from the bottom of the bag with a syringe.
- In a drier medium, obtain 2 cups of medium from a single bag or several bags. Mix the sample with distilled water until a saturated paste is formed, then drain through a filter to collect enough water for a test sample.

Fertilizer Injector Unit

For bag culture tomato production, a positive displacement type of fertilizer injection unit with four or five multiple heads should be used to inject fertilizer into the irrigation water (Fig. 7). The Anderson ratio proportion unit is the most common unit used in the U. S.

Irrigation Application

Agrifim button emitters with one-half gallon per hour capacity at 20 psi and attached to a "spaghetti tube" line to the plant are recommended for this type of water application in bag culture (Fig. 8). The water may be placed in the medium at timed intervals throughout the day to replace the water which has been taken up and transpired by the plants. The application of water should be based on the periods of greatest solar loading. Additional waterings should be spaced out in the morning and afternoon. It is not necessary to apply water at night if proper water applications are being made during the day.

FIG. 8.—"Agrifim" irrigation system for automatic watering of plants.

RESULTS

Yielding Ability of Bag Culture Tomatoes

Four cultivars of greenhouse tomatoes were tested in bags in the Spring of 1981. Yields ranged from 18.1 lb to 19.5 lb per plant of marketable fruit (Table 2).

More recently, plants in 0.75 ft^3 bags were compared side-by-side to soil-grown plants. Plants grown in bags produced 1.4 lb more fruit per plant than the soil-grown plants (Table 3). This yield difference was due to larger fruit size from the bag-grown plants.

TABLE 2.—Yields of Four Varieties of Greenhouse Tomatoes Grown in 0.75 cu ft Bags in the Spring of 1981.*

Variety	No. of Fruit per Plant	Av. Fruit Wt. (oz)	Lb Fruit per Plant
Dambito	55.40	5.3	18.1
Hybrid 7	59.50	5.3	19.5
Hybrid 9	57.35	5.3	18.9
MR-13	55.44	5.6	19.1

*Transplanted to bags 2/12/80. Plants pulled out 7/13/81.

TABLE 3.—Yields from Tomato Plants Grown in 0.75 cu ft Bags vs. Soil-Grown Plants.

Plant Growing System	No. of Fruit per Plant	Av. Fruit Wt. (oz)	Lb Fruit per Plant
Bags	44.9	6.4	18.0
Soil	45.4	5.8	16.6

CONCLUSIONS

On-going research which will further define the relation of energy conservation in greenhouses and its effects on the various cultural parameters of tomato plant growth and yielding ability is currently in progress. Growth of tomatoes in bags has been shown to be equally as successful if not better than growth in ground beds.

Other general cultural guidelines for growing tomatoes in bags are the same as those for ground beds. Recommendations for those requirements can be found in the publication, Growing Greenhouse Tomatoes in Ohio (2).

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